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Effect of Solar Power Plant Tilt Angle on Optimization Energy Generated in The Battery for Irrigation Rice Field Irrigation in Nagari Batu Taba

Junaidi Asrul[a], Rahmi Berlianti[a],Firmansyah[a], Fitriadi[a], Taufik Rahmadinata[b]

[a] *Department of Electrical Engeenering, Politeknik Negeri Padang*
Corresponding author: rahmiberlianti@pnp.ac.id

Abstract*— One of the promising new renewable energy sources in Indonesia is solar power plants (PLTS), which utilize solar energy as a renewable source and convert it into electrical energy. The methodology used in this study is a direct experiment to the field, by positioning the solar panel at an angle of inclination of 5°, 10°, 15°, 20°, and 25° using a digital inclinometer to measure the angle of inclination, a multimeter is used to measure the voltage produced and measuring the intensity of solar radiation using a lux meter. The purpose of this study is to find out the angle value and voltage produced by solar panels when facing north and east by using three solar panels of 200 Wp, Mppt 100 A, 12V/100 ah battery, and a 500 W inverter. The highest sunlight intensity of 795 was obtained at the position of the solar panel facing north with an angle of 15°, the intensity of sunlight with the angle of inclination used will affect the voltage produced. The highest voltage is obtained in the north-facing solar panel position with a voltage of 20.1 Volt at an angle of 15°. The highest battery voltage is measured when the solar panel is facing north with a tilt angle of 15°.

***Keywords*— Renewable Energy, Power Plant, Tilt Angle. Sunlight Intensity.**

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I. INTRODUCTION

One country with a lot of promise for renewable energy is Indonesia. Since solar energy is one of the infinite sources of energy, it is often used to generate electricity. Indonesia receives about 1200 w/m2 of solar intensity daily, which is rather high considering that it is in the equatorial region [1]. Solar Power Plants (PLTS) can be implemented at various scales, from household installations to commercial or centralized power generation facilities, and have a *wide* range of applications in the energy sector, including residential, commercial, industrial, and public infrastructure. In Indonesia's agricultural sector, the potential of solar PV is huge and offers significant benefits in various dimensions of agriculture, such as productivity, operational efficiency, and sustainability.

The current demand for electrical energy still depends on fossil energy sources which have limitations in their availability. Therefore, in the future, the use of renewable energy is an alternative that needs to be developed as it is in the development of solar power plants as an energy source to replace fossil energy sources [2].

The problem with solar power plant installations is that the voltage generated is erratic due to variations in sunlight intensity. The amount of solar intensity received by solar panels is directly correlated with the power generated by the photovoltaic system. The more solar radiation the panels receive, the more power the photovoltaic system can generate. Many factors, including astronomical location, the location of the panels, the apparent daily and annual movements of the sun, and the weather, affect how much solar intensity the solar panels receive [3]. The optimal tilt angle of a solar panel is one of the main factors in determining the maximum amount of solar radiation that can be absorbed, thus affecting the output power of the solar panel. Therefore,

research is needed to determine the best tilt angle so that solar panels can receive maximum sunlight which will affect the voltage produced later[4].

The solar PV surface slope factor has a significant impact on the electrical energy generated, which is one of the many parameters that need to be takeninto account when building a system. To optimize the amount of sunlight that solar panels receive, the system design must determine the optimal level of inclination for the panels to maximize solar radiation. Sunlight radiation is the light energy emitted by the sun to the earth's surface due to emissions from the earth and high-temperature incandescent gas. The intensity and spread of sunlight reaching the earth is affected by a variety of factors, so the amount of radiation received can vary [5]. The installation of solar panels is affected by two different types of angles: the azimuth angle, which is measured in the direction of the southern reference, and the angle of inclination of the solar panel to the horizontal plane, commonly referred to as the inclination. Many environmental factors may have an impact on the performance of solar cells, such as temperature variations, the amount of solar radiation, and partial closure of the cell's surface (shadow) [6].

Indonesia is located along the equator and has quite high daily solar radiation levels, with an average of around 4.5 kWh/m² per day. This condition is the main potential in the development of solar energy-based power plants. One of the main components in a photovoltaic system is a solar cell, which plays a role in converting sunlight energy into electrical energy [7].

In this study, which discusses the effect of the angle of inclination of solar panels on the solar radiation received by solar panels which cannot receive maximum exposure to sunlight throughout the day, resulting in the resulting efficiency is not optimal. In this study, we will formulate how the influence of changes in the angle of inclination of solar panels on the current produced.

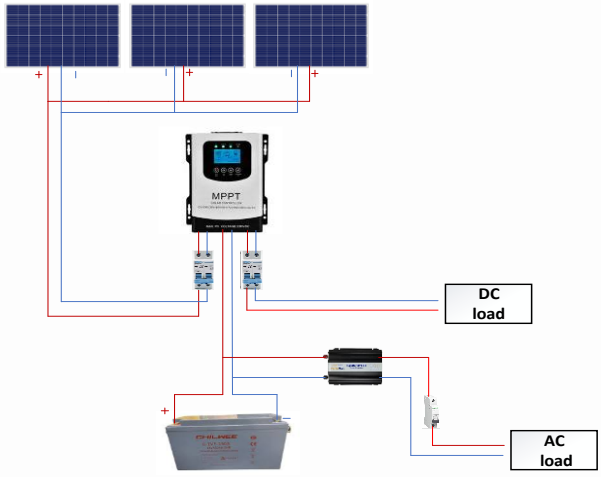


FIGURE 1. Solar Panel Installation Along with other Supporting Components

A. *Solar Panels*

The main component of a solar power generation system that directly converts solar radiation into electrical energy is the solar panels. Where solar panels are placed, a number of environmental factors, including temperature, sunlight intensity, direction, and spectrum, affect how much power is generated during the conversion process. Constantly changing environmental conditions result in fluctuations in the output power of solar panels [8].

B. *Maximum* Power Point Tracking

The electronic system that controls photovoltaic (PV) or solar cell modules to generate as much power as possible for solar cell modules is called Maximum Power Point Tracking, or MPPT for short. MPPT is an electrical system that, if taken in its entirety, modifies the electronic work point of a solar cell module to allow it to transmit as much power as possible. The extra power collected from the solar cell module allows for an increase in the charging current of the battery. Although mechanical tracking systems and MPPT can be connected, they are completely different [9]

C. *Inverter*

An inverter is a device that converts direct current (DC) voltage into alternating current (AC). The inverter's job is to convert the DC input voltage into a symmetrical AC output voltage with the appropriate frequency and magnitude. At fixed or variable frequencies, the output voltage may have a fixed or variable value. By changing the DC input voltage while maintaining constant inverter gain, a variable output voltage can be generated. In contrast, a variable output voltage can be achieved by changing the inverter gain if the DC input voltage is constant and cannot be controlled. Pulse-Width-Modulation (PWM) and Sinusoidal Pulse Width Modulation (SPWM) controllers of inverters are commonly used to adjust the gain of the inverter [10].

D. *Battery*

Equipment with electrical cells to store energy that can be converted into electricity is called a battery. Batteries use chemical reactions to generate electricity. Batteries are electrical cells that efficiently carry out reversible electrochemical reactions [11].

II. METHOD

In this study, we analyzed the tilt angle of the 600 Wp solar panel to the electrical power to be produced. The method used is to make observations directly in the field, where in this study the author made observations at a location located in Nagari Batu Taba. The process carried out in the test includes measuring the intensity of sunlight, the angle of inclination of the solar panel and the voltage on the solar panel. With the position of the solar panels facing east and north at 15.00 WIB

1. Conducting a Literature Study
   Examine the influence of tilt angle on the performance of solar panels and identify factors that will affect the efficiency of solar panels, such as tilt angle, sunlight intensity and temperature on solar panels
2. Design and Selection of Research Methods
   - Designing and selecting methods to be carried out in the research such as, conducting direct testing with the angle of inclination and direction of solar panels that have been determined.
   - Determine the tools used such as Lux meter (to measure the intensity of sunlight), waterpas (to measure the angle of inclination of solar panels), compass (to indicate the cardinal direction) and multimeter (used to measure the voltage on solar panels)
3. Comparative Data Collection
   Solar panels are installed with a predetermined direction and angle, data on voltage, tilt angle, direction on the solar panel and sunlight intensity are taken. By making these measurements, certain data is obtained to bias to vary more representative data.
4. Data analysis
   The data that has been obtained is analyzed to obtain a pattern between the angle of inclination, the intensity of sunlight in the direction of the solar panel and the voltage produced, a comparative analysis of the two positions of the solar panel is carried out
5. Conclusion
   From the results that have been obtained, get the optimal tilt angle and position for solar panel installation



(a) (b) (c)

FIGURE 2. Shows the tools used in measuring solar panels

From the picture above, there are equipment used to make measurements, such as (a) a lux meter which is useful for measuring the intensity of sunlight, (b) a multimeter for measuring the voltage produced from solar panels and a compass as a guide to the cardinal directions.

A. Research Workflow

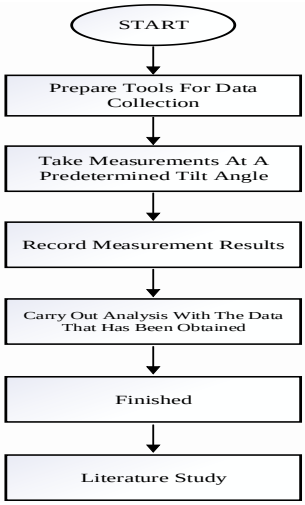


FIGURE 3. Flow Chat Research

B. Tool Working System

The workings of this solar panel system utilizes the tilt angle to maximize the voltage produced. By setting the direction (facing east or north) and the tilt angle of the solar panel to 5°, 10°, 15°, 20°, 25°, the resulting voltage will be different for each measurement. The following are the working stages of a solar panel system:

1. The solar panel will receive solar radiation and then convert it into electrical energy in the form of DC voltage.
2. The voltage produced by the solar panels is distributed to the MPPT to adjust the voltage and current that will be distributed to the battery and load
3. From the MPPT it will be channeled directly to the battery as an energy storage area.
4. From the battery it is channeled to the inverter which is useful as a tool for changing DC voltage to AC
5. MPPT load output is directly distributed to the DC load

III. RESULTS AND DISCUSSION

A. Effect of Voltage Generated by Solar Panels on Tilt Angle

The voltage generated from a solar panel depends on the intensity of sunlight that the solar panel receives. By positioning the solar panel at a certain angle of inclination, the solar radiation received can be optimized by the solar panel, which causes the voltage generated to be optimal as well. In general, the slope of the solar panel module is adjusted to the latitude position and placement position.

B. Effect of Solar Panel Tilt Angle on Sunlight Exposure

In this study, the collection of data on the position or angle of inclination of solar panels to sunlight was carried out in order to find out the voltage produced. Data collection was carried out by taking 2 positions, namely facing East and North at 15.00. From the results obtained in the measurement, the effect of angle shift from 5°, 10°, 15°, 20°, 25° on the solar panel was then analyzed.

C. Effect of Solar Panel Tilt Angle on Generated Voltage

Solar Panel Test Data with Tilt Angle

TABLE 1.
Sunlight Intensity Testing Data Affected by Tilt Angle feverish

No	Hours	Solar Panel Derjat	Lux East	Condition	Lux North	Condition
1	15.00	5	560	bright	785	feverish
2	15.01	10	565	bright	788	feverish
3	15.02	15	570	bright	795	feverish
4	15.03	20	569	bright	788	feverish
5	15.04	25	567	bright	785	feverish

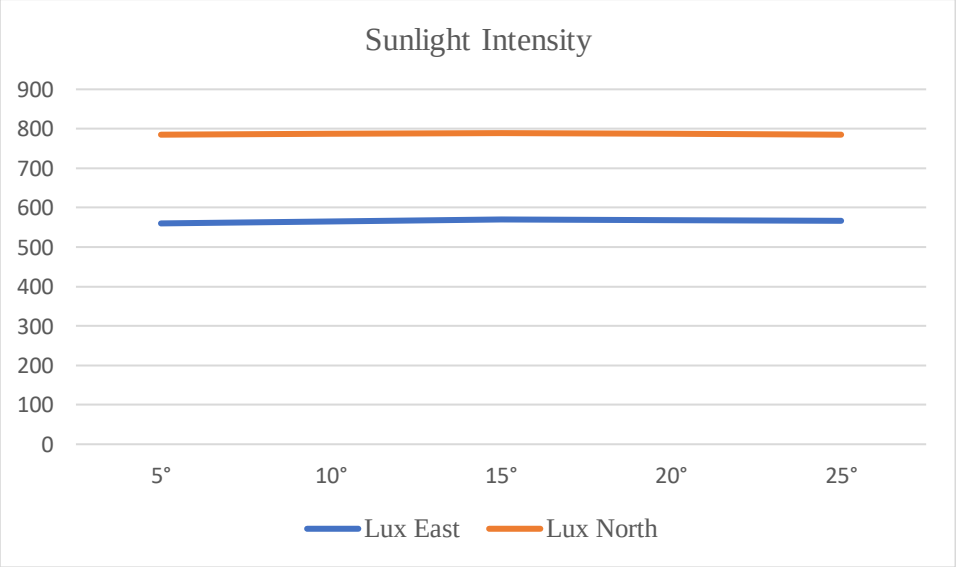


FIGURE 4. Graph of Sunlight Intensity On Solar Panels Facing East And North

As seen in table 1 above, the test was carried out by positioning the solar panels in two directions, namely north and east at 15.00 WIB. The first test was carried out by positioning the solar panel facing east with an inclination angle of 5°, 10°, 15°, 20°, 25°. The results of measuring sunlight intensity with changes in the angle of inclination of solar panels were not much different, in the measurements made the highest sunlight intensity at an angle of inclination of 15° with a sunlight intensity of 570 in sunny conditions.

The second test was carried out by positioning the solar panel facing north with a tilt angle of 5°, 10°, 15°, 20°, 25°. The results of measuring the intensity of sunlight with the change in angle that have been carried out are obtained, the results obtained are 795 at an angle of inclination of 15° with hot weather conditions. Figure 3 is a graph of the measurement of sunlight intensity generated from both tests with different angles and positions.

TABLE II
Solar Panel Voltage Testing Data With Affected Tilt Angle

No	Hour	Solar Panel Derjat	Solar Panel Voltage	
			East	North
1	15.00	5	18,85	19,94
2	15.01	10	18,87	19,97
3	15.02	15	19,92	20,01
4	15.03	20	19,59	19,9
5	15.04	25	19,49	19,89

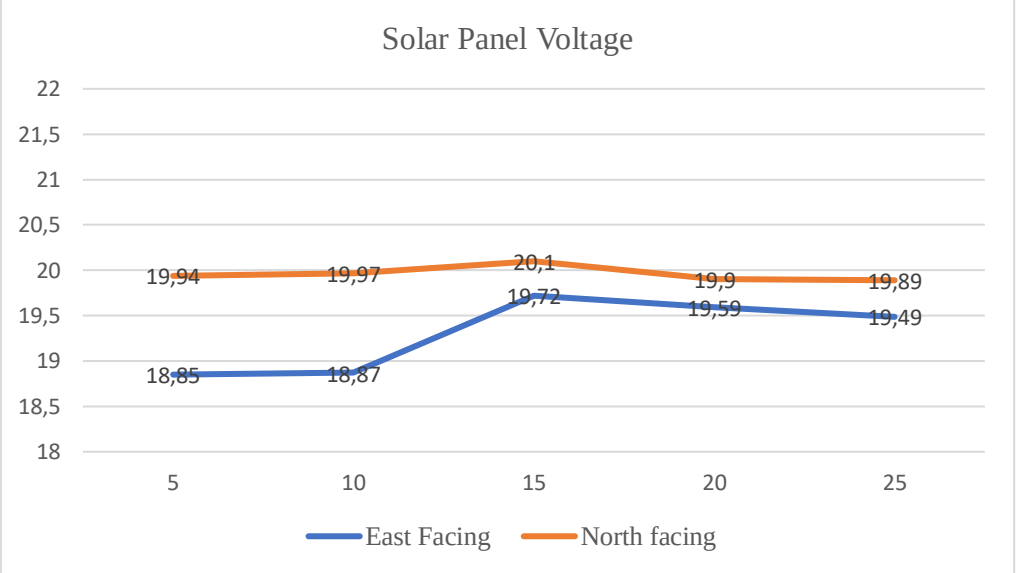


FIGURE 5. Solar Panel Voltage by Positioning the Solar Panel Facing East and North

Seen in table 2 above, this second test was carried out at 15.00 WIB to see the voltage produced by the solar panel by positioning it to the east and north with an angle of inclination of 5°, 10°, 15°, 20°, 25°. Testing with the solar panel facing East, the voltage generated by the solar panel from the starting angle of 5°, to 25° continues to increase. The highest voltage produced is at an angle to 15° with a voltage of 19.72 Volts.

The next measurement with the direction of the solar panel facing North, this time getting a stable solar panel output voltage at 19 Volts, in contrast to when the solar panel is facing east. The peak voltage at this measurement is at 20.1 Volts at a 15° angle of inclination. In figure 4, is a graph of the voltage generated by solar panels with tilt angles of 5°, 10°, 15°, 20°, 25°.

TABLE III
Battery Voltage Test Data Affected by Tilt Angle

No	Hour	Derjat Panel Surya	Battery Voltage	
			East	North
1	15.00	5	14,12	14,15
2	15.01	10	14,25	14,28
3	15.02	15	14,44	14,55
4	15.03	20	14,40	14,45
5	15.04	25	14,40	14,47

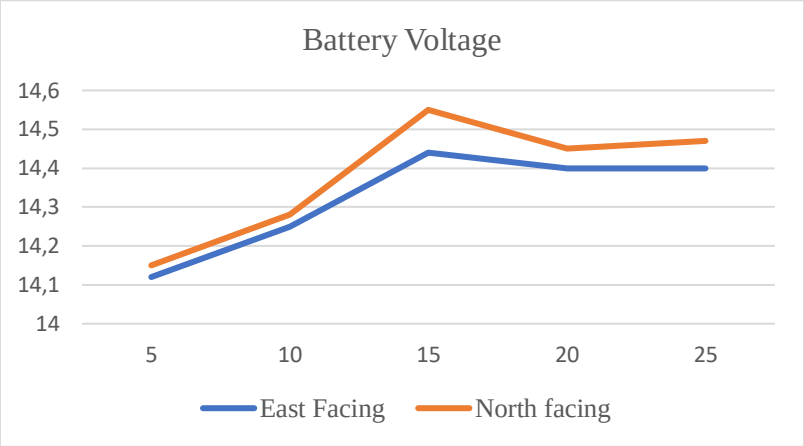


FIGURE 6. Voltage on the Battery by Positioning the Solar Panel Facing East and North

Seen in table 3 above is a voltage measurement table from the battery, the voltage generated from the solar panel will be directly channeled into the battery. The greater the voltage generated by the solar panel, the faster the battery will charge.

The first voltage measurement is carried out with the position of the solar panel facing east, the voltage produced continues to increase as the angle of the solar panel changes. Rated peak voltage on a 14.44 battery with a 15° tilt angle.

The next measurement was carried out by positioning the solar panel facing north, the voltage produced was 14.55 with an angle of inclination of 15°.

IV. CONCLUSION

From the research that has been carried out, it can be concluded that the position of the solar panel with a tilt angle of 5°, 10°, 15°, 20°, 25° and the position facing north or east greatly affects the voltage produced. At the intensity of sunlight, the highest measurement result was obtained of 795 with the position of the solar panel facing north at an angle of 15°. The intensity of sunlight received by solar panels greatly affects the voltage they produce, the voltage produced by solar panels is the highest of 20.1 with a north-facing position at an angle of 15°. The highest rated voltage on the battery is 14.55 when the solar panel is facing north at a 15° angle

REFERENCES

[1]. Abdurakman, Jaya. 2023. “Pengaruh Variasi Sudut Kemiringan Panel Surya Monocrystalline Terhadap Keluaran Daya Di Universitas Tidar Magelang.” Jurnal Elektro Universitas Tidar: 5–24.

[2]. Samsurizal, Samsurizal, Andi Makkulau, and Christiono Christiono. "Analisis pengaruh sudut kemiringan terhadap arus keluaran pada photovoltaic dengan menggunakan regretion quadratic method." Energi & Kelistrikan 10.2 (2018): 137-144.

[3]. Pangestuningtyas, D.L, H Hermawan, dan K Karnoto. 2020. “Analisis sudut panel solar cell terhadap daya output dan efisiensi yang dihasilkan.” Turbo : Jurnal Program Studi Teknik Mesin 8(2): 0–7.

[4]. Ali, Syurkarni, and TM Aziz Pandria. "Penentuan Sudut Kemiringan Optimal Panel Surya Untuk Wilayah Meulaboh." Jurnal Mekanova: Mekanikal, Inovasi dan Teknologi 5.1 (2019).

[5]. Albahar, Abdul Kodir, and Muhammad Faizal Haqi. "Pengaruh Sudut Kemiringan Panel Surya (PV) Terhadap Keluaran Daya." Jurnal Elektro 8.2 (2020): 115-122.

[6]. Energi, Jurnal. 2018. “Analisis Pengaruh Sudut Kemiringan Terhadap Arus Keluaran Pada Photovoltaic Dengan Menggunakan.” 10(2): 137–44.

[7]. Pangestuningtyas, D. L., Hermawan Hermawan, and Karnoto Karnoto. "Analisis pengaruh sudut kemiringan panel surya terhadap radiasi matahari yang diterima oleh panel surya tipe larik tetap." Transient: Jurnal Ilmiah Teknik Elektro 2.4 (2014): 930-937.

[8]. Fachri, Muhammad Rizal, Ira Devi Sara, dan Yuwaldi Away. 2015. “Pemantauan Parameter Panel Surya Berbasis Arduino secara Real Time.” Jurnal Rekayasa Elektrika 11(4): 123.

[9]. Faizal, Ahmad, dan Bagus Setyaji. 2019. “Desain Maximum Power Point Tracking (MPPT) pada Panel Surya Menggunakan Metode Sliding Mode Control.” Jurnal Sains, Teknologi dan Industri 14(1): 22–31.

[10]. SAODAH, SITI, dan SRI UTAMI. 2019. “Perancangan Sistem Grid Tie Inverter pada Pembangkit Listrik Tenaga Surya.” ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika 7(2): 339.

[11]. Hamzah, Sevira Rambanisa, Chairul G Irianto, dan Ishak Kasim. 2019. “Sistem PLTS Untuk Pompa Air Irigasi Pertanian di Kota Depok.” Jetri : Jurnal Ilmiah Teknik Elektro 17(1): 73–86.